IS THERE A LARGE-COUNTRY ADVANTAGE IN HIGH-TECH?

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Abstract

High-tech is a commonly used catch-word for industries that use a relatively large share of their resources on R&D and develop many new products and processes. It is a widely held view that high-tech is good for growth, and that countries that succeed in high-tech industry perform well. Schumpeterian theory, as well as the more recent “new growth” theories, are often quoted in support of this view. However, the “new growth” theories also suggest that large countries are more likely than small ones to succeed in high-tech. This paper explores empirically the factors behind success or failure in high-tech industry for a sample of OECD countries from the 1960s to the 1980s. It is concluded that although there exists a group of high-tech industries for which the scale of the country seems to matter a lot, this does not extend to all industries where R&D and innovation are important. However, cost competition tends to be more severe in those industries where small countries can compete on equal terms. Thus, small countries do to some extent face a greater challenge in high-tech than large countries

1. Introduction

High-tech is a commonly used catch-word for industries that use a relatively large share of their resources on R&D and develop many new products and processes. Sometimes it is argued that one should also include industries that make intensive use of products with a high R&D content, even if they do not spend much on R&D or develop much new technology themselves. Although this broader definition may be interesting for some purposes, in this paper we will stick to the more commonly used, narrow definition. This restricts the concept, high-tech, to industries that innovate.

To explain why high-tech is important, we need to focus on the links between innovation, growth and trade. The classic reference is Schumpeter (1934, 1939, 1943). In his theory of industrial development, innovation is assumed to be the single most important competitive factor. Innovative firms have a temporary monopoly which allows them to charge higher prices and, hence, be more profitable than other firms. They will also grow faster, partly because they have the market temporarily for themselves, and partly because their higher innovative ability implies that they are more competitive in the marketplace. There is also a stimulus from the demand side, sinde the growth of demand for goods based on new technology generally outstrips the growth of demand for goods based on older technologies. For technological as well as economic reasons, Schumpeter expected innovations to cluster in some (R&D-intensive) industries. Production in these industries should be expected to experience above average growth. The same goes for trade. In fact, from the 1960s to the 1980s the share of high-tech in world trade (as defined in this study) roughly doubled.

Thus, high-tech means high growth, and this probably explains the general concern in many countries for the fate of high-tech industries. Indeed, it seems to be a widespread view among policy-makers that success in high-tech industry (and exports) is a good recipe for high growth in national income. Recently, this view has got greater academic credibility to the advent of "new growth theories" emphasizing the importance of innovation and organized R&D for economic growth (Romer 1990, Grossman and Helpman 1991, for an overview see Verspagen 1992). But what determines the extent to which a country succeeds in specializing in high-tech? When this question was first raised in the 1960s, it became apparent that traditional trade theory (Hecksher-Ohlin) had relatively little to say about the subject. This led to the formulation of so-called "neotechnological" trade theories, to a large extent inspired by Schumpeterian perspectives (for an overview, see Dosi and Soete 1988). These theories and subsequent empirical work based on this perspective suggested a link between a strong competitive position in high-tech trade and domestic R&D

efforts: "All roads lead to a link between export performance and R&D" (Gruber, Metha and Vernon 1967, p. 22).[1] The importance of R&D and innovation for trade performance was also demonstrated empirically by Lacroix and Scheuer (1976). More recently, Soete (1981, 1987) and Dosi and Soete (1983) have provided additional evidence for the view that national technological activity, measured through R&D or patent-statistics, matters for export performance in high-tech (and some not-so-high-tech) industries.

The policy implication of much of this seems to be that a country can affect its chance of success in high-technology industries by devoting resources to R&D. However, some recent theoretical works indicate that it may not be so simple. For instance, some "new growth theories" suggest that while R&D-efforts matter for high-export, so does country size (see Grossman and Helpman 1991). These theories emphasize that R&D efforts generate technological spillovers that facilitate (reduce the cost of) subsequent R&D projects (or innovations). Since a large country does much more R&D than a small one, there will be more spillovers and lower costs of innovative activity in the large country. Hence, in the long run a large country may gain the upper hand in high-tech even if it at the outset devotes a smaller share

[1] Another suggestion was that innovation was facilitated by advanced domestic demand (Linder 1961, Vernon 1966), for an empirical test of this view see Fagerberg 1995, forthcoming.

of its resources to organized R&D than a smaller one.[2] This result, which obviously rests on the assumption of geographical limitations on technology spillovers, may have important implications for policy. To the best of our knowledge there is not much empirical work that investigates the joint impact of national technological activity, country size and other factors on export performance. This paper is a modest attempt to throw some more light on this issue.

2. The design of the test

The analysis that follows is based on the commonly used assumption that (a) **a country's specialization pattern in international trade** results from the interaction between (b) **industry specific conditions of competition** and (c) **country specific capabilities**. Knowledge about any two of these may then be used to make inferences about the third element, in this case the conditions of competition at the industry level. Basically, this is the methodology proposed by Leamer (1974). However, while Leamer starts from the traditional factor abundance theory, we apply a

[2] This may be seen as a special version of the more general prediction of so called "new trade theory" (Helpman 1984); that countries with small domestic markets may face a potential disadvantage in industries where economies of scale prevail if products are differentiated or there are barriers to trade (protectionism etc.).

more eclectic model that allows for variables consistent with different theoretical approaches. Nevertheless, our point of departure will be the Schumpeterian inspired models discussed in the preceding paragraph.

The model to be tested is set out in equation 1 below. For reasons that will become apparent, a log-linear form was preferred:

$$\log S_{ij} = a_o + \sum_{l=1}^{m} a_i \log C_{lj} \qquad (1)$$

where:

S_{ij} = Specialization index (RCA) for country j in commodity group i

C_{lj} = Set of capabilities (l) for country j

To measure specialization, we use the familiar index for revealed comparative advantage (Balassa, 1965). For a particular country and product, this index is the *ratio between the market share of the country on the world market for this particular product and the market share of the country on the world market for all products*. This index has the property that the weighted mean is identical to unity for each country across all commodity groups, and for each commodity group across all countries. Thus, a country is said to have a revealed comparative advantage (be specialized) in a product if the RCA index exceeds unity. However, the index has a skew distribution, with a long tail to the right. This creates problems in regression analysis, because it violates the assumption of normality. Since a logarithmic transformation of the data reduces this problem significantly, a log-linear functional form was preferred (equation 1 above).

The calculation of the RCA index draws from a database[3] on OECD trade (value data[4]). The data were aggregated into 41 product groups (see table 1). Great care was taken to ensure that R&D-intensive products as well as products based on important, commercially successful innovations in the not too distant past were specified as separate products, while more mature products and raw materials were treated in a more aggregative way. The identification of the R&D-intensive products was based on other studies (Kelly 1977, Aho and Rosen 1980, OECD 1985). While the two

[3] The database was constructed jointly by Bent Dalum (at the University of Aalborg) and the author from OECD Trade Series C. See Fagerberg (1986) for details.

[4] It is often suggested that it would be preferable to use volume data instead of value data, but this was not possible at a sufficiently disaggregated level. Furthermore, volume data are problematic in cases where substantial technological changes occur and become, for the very same reason, less reliable when the time span under consideration grows. For instance, it is very difficult to compare the trade volumes of, say, computers in the 1960s and the 1980s, since it is not clear how "volume" in this case should be defined.

earlier studies were based solely on US data, the last one uses data for a group of OECD countries. However, with a few exceptions, these studies end up with rather similar rankings of products according to R&D intensity (expenditures on research and development as a share of output or sales).[5]

From the 41 products included in the classification, raw materials, where comparative advantage probably depends on the domestic supply of natural resources, and residual categories were excluded from the investigation. The remaining 28 products accounted for 61.2% of total OECD exports in 1983. The single largest group was cars, which alone accounted for 11.0% of total OECD exports that year, the share of the others varied from 0.2% to 5.7%.

One of the problems in this study, as in most econometric studies of export specialization, is the selection of explanatory variables and proxies. Indeed, the potential number of factors that could have been taken into account is very large. Here we

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[5] It should be noted, though, that a few products classified as R&D-intensive in the two earlier studies, did not appear as such in the last study (non-electronic office machinery (typewriters etc.), consumer electronics and cars). Probably this reflects that these products, by the early 1970s, had entered the mature phase of the product cycle. We have chosen to regard these as R&D intensive prior to 1973, but not later. Thus, we end up with two lists of high-tech products, a broad one, applicable for the 1960s and early 1970s, and a more narrow one, assumed to be appropriate for the most recent period.

have to rely on theoretical considerations and the specific purpose of the study. The basic model will be one where comparative advantage is created through technological capability, measured through R&D or patent statistics, and challenged by imitators exploiting cost advantages (low wages). To this framework we add variables reflecting various factors that are often alleged to have an important impact on export specialization. One of these, which follows from the purpose of this study, is the country size or scale variable, here proxied by the size of the population. Since it is often argued that military demand has been an important factor for the creation of competitive advantage in many high-technology industries, we also included military expenditures as percentage of GDP as a possible explanatory factor. Finally, to be able to account for the possibility of differing requirements of capital across industries, we included gross investment as a share of GDP. Since raw materials were excluded from the investigation, we did not include any variable reflecting relative "abundance" of natural resources. Admittedly, many of these variables are of a rather crude nature and, as in most other econometric studies of export specialization, the results should be taken as just indicative. Below follows a list the explanatory variables included in the test. For sources, see appendix.

- Research and development (RD): Total R&D expenditure as a percentage of GDP.

- Patents (PAT): External patent applications adjusted for country size and the openness of the economy.[6]

- Wages (WAGE): Wage per hour in common currency.

- Scale (POP): Population of the country.

- Military demand (MIL): Military expenditure as a percentage of GDP.

- Investments (INV): Gross investments as a percentage of GDP.

As will often be the case, some of these variables may be open for rival interpretations. For instance, the investment and wage variable could be interpreted as reflecting "endowments" of capital and labour respectively (the traditional factor-proportion - or Hecksher-Ohlin - theory). By stretching the argument somewhat, R&D expenditure could be interpreted as reflecting the "endowment of skilled labour", on which R&D activity obviously depends (the so called neo-factor proportion theory). Patents, scale and military expenditure, however, are variables that hardly fit into a neo-factor proportion framework. In any case,

[6] The reason for adjusting the index for differences in the degree of openness of the economy is that the propensity to patent in foreign markets is assumed to depend on the importance of export markets relative to the domestic market (see Fagerberg 1987).

considerable doubts may be raised about the usefulness of the neo-factor approach. Arguably, to label something "endowment" - when it clearly reflects conscious human behaviour - does not constitute much of an explanation.

The data refers to different time periods between 1960 and 1983. 19 OECD member countries were included.[7] For the dependent variable indices were calculated for 1969, 1973, 1979, and 1983. The data for the independent variables were calculated as average values for the preceding periods (1960 to 1967, 1968-1973, 1974-1979 and 1980-1983) allowing for an average lag of roughly 3 years. Since the dependent variable, the revealed comparative advantage index, is a normalized variable, we decided to normalize all the independent variables in the same way. This implies that, for each country (and year), the value of each independent variable was divided by the across-country mean of that variable.[8]

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[7] These are: USA, Japan, Germany (west), France, UK, Italy, Canada, Austria, Belgium, Denmark, the Netherlands, Norway, Sweden, Switzerland, Finland, Ireland, Spain, New Zealand and Australia.

[8] Some countries had values for the RCA index close to zero in some sectors. In order to avoid extreme values in the regressions (a logarithmic specification was used) we restricted the lower end of the observations to 0.1 by adding 0.1 to all observations of the dependent and the independent variables. Thus, the average for each variable in each year is 1.1, not 1.0.

3. Results.

Three different tests were carried out: a pooled test (all time periods combined), a mean test (regression between the within country means across years of each variable) and a difference test (a regression between the difference between the final observation and the first observation of each variable).

The advantage of a pooled test is that it combines information on the static and dynamic aspects of the model, and allows for a much greater sample than could otherwise have been used. The problem is that specification problems, in particular the omission of country specific variables, may result in residual correlation within the cross sectional units. To test for this we applied the Durbin-Watson test adjusted for gaps. The test indicated that residual correlation within the cross-sectional units was a problem. Methods to remedy this consist of excluding, totally or in part, that share of the total variance that can be associated with the within-country means of the variables (Maddala 1977, Johnston 1984). These methods are problematic in cases where the within-country means are considered to be important as explanatory factors, especially if some of them do not change much trough time, as is the case for many of the variables considered here. We decided, therefore, following one of the suggestions made in the econometric literature,[9] to supplement the pooled test with separate tests for the statics and dynamics of the model.

The interpretation of the two additional tests is as follows. The mean test is a test of the long run implications of the model, or to what extent **the structure of comparative advantage** (or export specialization) within each product group for the period as a whole can be explained by the independent variables included in the test. The difference test, on the other hand, tests the extent to which **the changes in the structure of comparative advantages** during the period of investigation can be explained by **changes** in the variables included in the test. This opens for the possibility that the determinants of the existing pattern of specialization across countries differ from those explaining the dynamics of this pattern.

In each case a backward search for the model with the least variance was used. The reason why we included both a R&D-based measure and a patent-based measure in the regressions, even though these are known to be heavily correlated across countries (Fagerberg 1987, 1988), is that other studies have shown that the significance of these two variables differ across sectors. So, even if only one of them usually will be retained, we found it advisable to start the search with both variables included.

The results are reported in tables 2-4. Restricted R^2 and

[9] See Maddala (1977) p. 326 and Johnston (1984) p. 405-6.

variables that were significant at a 10% level or more are included (for the others we accepted the proposition that their impact was not significantly different from zero). The main results may be summarized as follows:

1) If we restrict ourselves to products where one or more factors were significant at a 1% level in the pooled test, and at a 5% level in at least one of the two supplementary tests, there were twenty products that met these criteria and eight that did not. The latter were: paper, textiles, steel, aluminium, fertilizers, office machinery, domestic electrical equipment and furniture. Together these eight products accounted for 13.4% of total OECD exports in 1983 (or roughly one fifth of our sample). Of these eight products, six come from industries processing raw materials. For these a possible explanation may be that success depends on "relative abundance" of important resources (including, perhaps, cheap energy) not taken into account in the test.
2) The clearly most important factor according to the above criteria was technology, which was significant in fourteen of the twenty cases mentioned above. But also the wage-level was found to be important (ten cases). The scale variable turned out to be significant in six cases and the two remaining factors, military demand and investments, in two cases each.

The explanatory power of the different factors (in terms of number of significant estimates) is reflected in the different sizes of the circles in graph 1. If the products had been weighted according to their shares in total OECD trade, the differences in explanatory power between the technology, wage and scale variables would have been smaller, but technology would still had been the most important factor. In 1983 the share in total OECD exports of the products for which technology was found to be an important factor was 29.9%. The shares for products where wages and scale were relevant were 24.3% and 20.7%, respectively.[10] The shares of products in which the two remaining factors, military demand and investments, were important were 3.0% and 2.2%, respectively, i.e. not very large.

3) As Graph 1 shows, there are many cases of overlap between the various factors, especially between technology on the one hand, and wages and scale on the other. But there was only one case of overlap between wages and scale, semiconductors, for which also technology was found to be important factor. Thus, with the exception of semiconductors, the products for which technology was found to be an important factor divide neatly in three: one group where technology and scale (but

[10] It should be noted, however, that the size of the share for the scale factor depends very much on one product group, cars, which alone accounted for 11.0 % of total OECD exports in 1983.

not wages) are important (two products), another where technology and wages (but not scale) are important (eight products) and finally one where only technology matters (four products). The most important of these, numerically and economically, is the one where technology and wages matter. In 1983 this group alone accounted for 21.5 % of total OECD trade.

4) If we adopt the stricter criteria of products where one or more factors were found to be significant at a 1% level in the pooled test and at a 5% in **both** the supplementary tests, the dominant role played by technology is strengthened. In this case technology was found to be a significant factor in eight products, compared to one product each for scale and investments and no product for wages and military demand. Thus, technology is the only factor that has sufficient explanatory power to explain both the statics and the dynamics of the model.

5) When the dynamics is tested separately (table 4), the important role played by technology is again confirmed. If the 5% level of significance is adopted, technology turns out as a significant factor (with correct sign) in eleven products, compared to two for wages and one for scale.[11] It

[11] In the case of the scale variable it should be mentioned that since this variable is relatively stable through time, it should be expected to lose much of its impact in a test of this type irrespective of whether the hypothesis under test is true or

is interesting to note, however, that the investments variable performs much better in this test (significant at a 5%-level in seven products) than in the other two, i.e. that growth in comparative advantage and growth in investment activity are positively correlated in many cases.[12] The same applies, although not to the same extent, to growth in comparative advantage and growth in military expenditure (four products).

If we compare the results obtained here with the R&D-intensity of products as reported by other sources (see table 1), some important similarities, as well as differences, emerge. First, out of the thirteen goods that are classified as R&D intensive in table 1, eight are included in the group where technology was found to have a significant impact. All but one belong to the group of products for which technology was found to affect both the statistics and dynamics of the model (see point 4 above). The remaining five R&D-intensive products are distributed

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false. The same applies - although perhaps not to the same extent - to some of the other variables.

[12] It might be suggested that this result supports the factor-abundance theory. However, this theory would also predict a positive relation between the level of comparative advantage and the level of the investment-ratio (as a proxy for capital intensity). As follows from table 3 this was the case for two products only (inorganic chemicals and ships).

with three in the group where scale was found to be the most important factor (cars, computers and aircrafts - the latter in overlap of military demand), one in the group where investment matters most (again in overlap with military demand) and one in the group for which no significant explanatory factor was found. The latter, office machinery, was one of a few products that were classified as R&D-intensive prior to 1973 but not later, indicating increasing maturity (and, hence, change of explanatory factors) during the period of investigation.

The findings of this study suggest that **a distinction must be made between technology (including R&D) as an input in the process of production and as the most decisive factor in the process of global competition.** Industries such as aircrafts, computers and - to a lesser extent - cars are clearly among the most R&D intensive, but comparative advantage in these industries is determined by access to a large domestic market rather than by differences between countries in R&D efforts.[13] This finding lends some support to the argument by some new-growth theorists that large countries are more likely to develop a comparative advantage in high-tech.

However, the results of this study also point to another difference between R&D as an input and technology as an important

[13] Van Hulst et al. (1991) also found that technology variables had little explanatory power in some "very high-tech" industries.

competitive factor. **The list of products for which technology was found to be an important factor is broader than the list of R&D intensive products or industries.** In particular it includes a larger part of the machinery and chemical sectors. This relates, for instance, to various types of general and specialized equipment for use in the industrial sector. As is clear from tables 2-4 it is the inclusion of the patent variable that produces this result. Thus, in these industries, competition through technological innovation is important, but it is not necessarily related to the intensity of R&D. This result is in accordance with the findings of a number of innovation studies showing that innovations in these sectors are more related to engineering activities, often in interaction with customers and suppliers, than to organized R&D (Pavitt, 1984). Since scale factors do not seem to be important in these industries, the opportunities for small countries are probably better here. But, in contrast to the cases where scale-factors were found to be important, most of these industries are also exposed to cost competition (wages).

How are these findings to be explained? One possibility suggested in the literature (Pavitt 1984, Nelson and Wright 1992) is that the process of technological progress differs in character between industries. In some industries, it is argued, innovations are science-based (result from organized R&D), written down (codified) and replicable. In other industries technological improvements continue to result from learning (by doing, interacting etc) and are, in contrast to the science-based ones, often "tacit" (uncodified) and "organizational" in character. Although these latter industries also use legal instruments (patents) to protect their innovations, the "tacit" and "organizational" character of the innovation process implies a high degree of protection in itself, i.e. that innovations from these industries are often not easily replicable. From this one might conjecture, using the language of the "new-growth" theorists, that technological externalities are much more frequent in the science-based industries than in the "learning"-based ones. Since the hypothesis of a large-country advantage in high-tech is based on the assumption that technological externalities are frequent, it is perhaps not surprising that the predictions does not fit all industries where innovation and, hence, technological competition, has been found to be important. This means, however, that the "new-growth" theorists have not succeeded in modelling technological progress in an all-encompassing way, and this puts some limitations on the validity of the predictions that can be obtained from this framework. Another critical point is that geographical limitations on technological externalities, which plays an important role for some of these predictions, cannot merely be assumed, but has to be explained (Fagerberg 1994).

There is also the possibility of alternative explanations of the impact of the scale, or country-size, variable. The six industries for which scale was found to be important were aircrafts, computers, semiconductors, consumer electronics, power-generating machinery and cars. These are all industries where non-tariff barriers to trade are known to be important. Governmental favouritism and subsidies have also been frequent. Thus, a more conventional explanation based on scale economics and trading costs[14] - caused by various forms of protectionism - might perhaps do the trick. The present study cannot discriminate between these different versions of the scale argument.

4. Comparison with other studies

There are few other studies that can be directly compared to this one. Studies based on correlation between some measure of export performance on the one hand and R&D performance on the other, such as Walker (1979), tend to turn up with a more narrow definition of high technology products than the one suggested here. The methodology applied in many of these studies also differs from the one adopted here by using industry specific data, often based on the US experience, as independent variables. One study, closer to

[14] See the survey by Helpman (1984) on trade models with imperfect competition and economies of scale.

the framework adopted here, is that of Lacroix and Scheuer (1976). They regress exports from 15 different industries on a set of country specific variables including scale factors, industry-specific R&D outlays, human capital and capital intensity. The level of aggregation does not allow for a detailed comparison with the results presented here. However, the general result was that R&D turned out as important in a broad range of industries including most chemical and mechanical industries. The impact of scale factors, however, is more difficult to assess because of the inclusion of two variables related to scale, GDP and population (the results indicate that a multicollinearity problem may be present).

A methodology similar to that of Lacroix and Scheuer has been applied by Soete(1987) and Dosi and Soete(1983).[15] In Soete (1987) the market share for exports was regressed on a set of country-specific variables reflecting sectoral innovative activity (external patents in the United States), population, capital intensity and "distance", for 40 sectors in 1977 (1963-1977 average for the patent variable). As in the present study technology was found to be an important factor in many sectors. This includes some of the (R&D-intensive) sectors mentioned earlier, where our study points to scale, not technology, as the

[15] See also Dosi, Pavitt and Soete (1990) where many of the empirical studies by Soete and others, including the two discussed here, are summarized and discussed.

most important competitive factor. The scale variable turned out as significant in a few sectors only, and with the exception of cars, in other sectors than the ones found here. However, as in the case of Laxroix and Scheuer, the way the variables are handled makes this result difficult to assess. Indeed, with the exception of the "distance" variable, all variables included in the test by Soete depend on the size of the country.

It should be noted that there is an important difference between the tests conducted here and those of Lacroix and Scheuer and Soete in the way the technology variables are defined. In our study these variables are calculated for the country as a whole and are assumed to reflect national technological capabilities. Lacroix and Scheuer and Soete, however, use sector specific data for the technology variable and aggregated data for the others. The implication is that the hypothesis under test is not exactly the same as in our study. While we test for the impact of national technological capabilities, they test for the impact of sector-specific technological efforts. These do not have to be related (although they often are). For instance, a country may for some reason be specialized in a particular product or industry where technological competition is important, and - consequently - have a high level of R&D and patents in that particular field, even if the general level of technological activity in the country is rather low.

Another difference between the tests by Lacroix and Scheuer and Soete and the tests presented here is that neither of them included a cost variable. However, this has been done by Dosi and Soete (1983) on roughly the same data. But in that study the scale variable was omitted and the cost variable defined in a way which made it a mixture of costs and income distribution. Thus, it is not possible to make direct comparisons between the results of our study and those obtained in earlier studies in this respect.

Still, here, as in earlier studies, technology is was found to be the single most important explanatory factor of export performance/export specialization. Table 5 compares the results obtained in our study with those presented by Soete (1987) with respect to the estimated technology elasticities. As is clear from the table the results are almost identical for non-electronic machinery. For electronics the results are more difficult to compare. In general, in our study these products appeared to be more related to R&D than to patents. The definitions of the product groups also differ somewhat. However, when care is taken to the fact that the mean of the estimated elasticities is higher for R&D than for patents, the results may be interpreted as being broadly similar. For chemicals, however, our study generally reports higher and more significant elasticities than those reported by Soete. Partly, this is due to the inclusion of R&D as an explanatory variable, but it does also hold for the cases for which patents were found to be the most significant factor.

5. Concluding remarks

This paper has raised the question of whether or not there exists a large country advantage in high-tech industries. **The results indicate that there exists a group of R&D intensive products where access to a large domestic market appears to be an important competitive factor, sometimes (but not always) in combination with a high share of military expenditure in GDP.** This includes aircrafts, cars, power generating machinery and a large part of electronics. The results also indicate that most of these products are not very sensitive to cost competition (wages).[16] The significant impact of country size on comparative advantage in these industries is consistent with the predictions of some new-growth theorists (based on the assumption that technology spillovers are national rather than international in scope). Another possible interpretation of these results is that there is a story of large country protectionism to be told here as much circumstantial evidence indeed suggests. To the extent that

[16] Indeed, for one group (cars), the results indicate that increasing comparative advantage and increasing wage costs vis a vis competitors are positively related (see table 4). This result is significant at the 1% level. If the level of significance is set to the 5 % level, similar results were found for two other groups, aluminum and power generating machinery.

protectionism is present, this reinforces the well-known argument from the trade literature that small countries has most to gain from reduced trade barriers (see, for instance, Krugman 1988).

However, this study also shows that technology is an important competitive factor in a large number of products or industries where scale factors are of little importance. These include a large number of engineering and chemicals industries. But with some exceptions, these products are also exposed to cost competition (wages). Thus, the challenges from industrializing, low-cost countries may be of greater importance for small than for large countries (although the public attention on this is at least as great in the latter). Nonetheless, the results also indicate that wage costs, although important, play a more passive role in global competition than technology.[17] Thus, small, developed countries are not doomed to specialize in mature, low-tech industries. The option for these countries appears to be to compensate for higher costs by a higher level of innovation and a more rapid process of diffusion. Hence, technology policy may be important in small countries as well. However, small countries

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[17] This is shown by the fact that wage costs, with two exceptions (telecommunications and instruments (5 % level)), failed to contribute to explanation of the changes in comparative advantages during the period of investigation (see table 4). By comparison, there were 11 products where one of the technology variables was shown to have an impact on these changes (5 % level).

should avoid imitating the technology policies of the large countries, which often concentrate resources on areas where large-country advantages seem to be present. Instead, small countries ought to focus on the large number of industries where technology - and innovation through learning - is important, but scale matters less.

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Appendix (Data Sources - Independent variables)

- External patent applications: OECD/STIIU DATA BANK and World International Property Organization(WIPO):Industrial Property Statistics.
- R&D: OECD Science and Technology Indicators
- Military expenditure as percentage of GDP: SIPRI Yearbook
- Other variables: OECD Historical Statistics and OECD National Accounts

Table 1 List of products SITC.Rev.1

101 PRODUCTS BASED ON NATURAL RESOURCES	
1 Animals, meat and meat preparations	00,01,091.3,411.3
2 Dairy products and eggs	02
3 Fish and fish preparations	03,411.1
4 Cereals and cereal preparations	04
5 Feeding-stuff for animals	08
6 Skins and leather manufactures	21,61
7 Wood and wood manufactures	24,63
8 Pulp and paper	25,64
9 Textiles	26,65
10 Iron ore	281
11 Iron, steel and ferro alloys	67
12 Aluminum	684
13 Other products based on natural resources	Rest 0-4 and 6, Less 33,34,69
102 OIL AND GAS	
14 Oil and gas	33,34
103 CHEMICALS	
15 Organic chemicals	512
16* Inorganic chemicals	513,514
17 Dyestuffs, coloring materials	53
18* Pharmaceuticals	54
19 Fertilizers	56
20* Plastics	581.1 and 2
21 Other chemicals	Rest 5
104 ENGINEERING, ELECTRONICS AND TRANSPORT EQUIPMENT	
22* Power-generating machinery	711
23 Machinery for special industries or processes	712,715,717,718 719.3,5 and 8
24 Heating and cooling equipment	719.1
25 Pumps and centrifuges	719.2

26* Typewriters and office machines	714.1 and 9
27* Computers and peripherals	714.2 and 3
28* Semiconductors	729.3
29* Telecommunications	724.9
30* Machinery for production and distribution of electricity	722,723,729.9
31* Consumer electronics	724.1 and 2, 891.1
32 Domestic electrical equipment	725
33* Scientific instruments, photographic supplies, watches and clocks	726,729.5 and 7, 861,862,864
34* Road motor vehicles	732
35* Aircraft	734
36 Ships and boats (incl. oil rigs)	735
37 Other engineering products	Rest 7,less 719.4
105 TRADITIONAL INDUSTRIAL PRODUCTS	
38 Manufactures of metal	69,719.4,812.2 & 3
39 Furniture	82
40 Clothing	84
41 Industrial products n.e.c.	Rest 8-9

* = High-tech

TABLE 2. REGRESSION RESULTS (POOLED TEST)

		$\bar{R}^2$	RD	PAT	INV	WAGE	POP	MIL
8	Paper	0.18	-0.58 (1.89) ***			1.09 (2.85) *	-0.26 (2.05) **	
9	Textiles	0.22	0.34 (1.92) ***			-1.05 (4.67) *		
11	Steel	0.12			1.36 (2.30) **	-0.41 (1.75) ***	0.18 (2.17) **	
12	Aluminium	0.24			2.17 (2.70) *	0.67 (2.02) **	-0.24 (2.29) **	0.80 (2.63) *
15	Organic Chemicals	0.34	0.66 (2.77) *	0.22 (1.69) ***		-1.06 (4.30) *		0.34 (1.79) ***
16	Inorganic Chemicals	0.34		-0.35 (3.74) *	2.25 (3.82) *		0.25 (3.48) *	1.02 (5.04) *
17	Colouring Materials	0.47		0.72 (5.49) *		-1.17 (4.62) *	-0.31 (3.98) *	
18	Pharmaceuticals	0.47	0.43 (1.82) ***	0.58 (4.38) *	-2.65 (5.15) *	-1.15 (4.82) *	-0.37 (4.74) *	
19	Fertilizers	0.27	0.75 (2.09) **	-1.00 (5.24) *			0.28 (2.46) **	
20	Plastics	0.39	0.72 (4.39) *			-0.96 (4.78) *		0.56 (2.67) *
22	Power Generating Machinery	0.55		0.39 (5.71) *			0.25 (4.44) *	
23	Special Machinery	0.62	-0.24 (1.78) ***	0.71 (9.25) *		-0.55 (4.13) *		
24	Heating and Cooling Equipment	0.25	-0.54 (2.25) **	0.55 (4.34) *				
25	Pumps	0.50	-0.31 (1.72) ***	0.67 (7.04) *		-0.60 (3.29) *		0.29 (2.17) **

26	Office Machinery	0.52		0.42 (3.28) *	-1.46 (2.91) *	-0.65 (2.80) *	0.26 (3.35) *	
27	Computers	0.33	0.48 (2.36) **				0.33 (3.76) *	
28	Semiconductors	0.48	1.08 (4.81) *			-0.92 (3.37) *	0.38 (4.34) *	
29	Telecommunication Equipment	0.34	0.78 (4.92) *		-0.76 (2.66) *		0.14 (2.19) **	
30	Machinery for Production & Distribution of Electricity	0.69		0.63 (12.5) *		-0.96 (8.31) *		
31	Consumer Electronics	0.53	0.98 (5.55) *				0.29 (3.80) *	-1.51 (8.45) *
32	Domestic Electrical Equipment	0.15	-0.50 (2.00) **	0.33 (2.38) **		-0.74 (3.01) *		
33	Instruments	0.64	0.85 (4.64) *	0.47 (4.95) *	0.86 (1.76) ***	-0.50 (2.82) *		-0.49 (2.68) *
34	Cars	0.45	0.58 (2.15) **	-0.32 (2.24) **			0.58 (6.75) *	
35	Aircrafts	0.72	0.34 (1.78) ***		-1.49 (2.84) *		0.41 (6.87) *	0.67 (3.62) *
36	Ships	0.19	-0.90 (2.58) *		4.95 (4.07) *			0.96 (2.22) **
38	Metal Products	0.48		0.34 (5.57) *		-0.79 (7.47) *		
39	Furniture	0.15	-0.54 (1.75) ***			-0.60 (1.91) ***	-0.27 (2.75) *	
40	Clothing	0.49		0.20 (2.00) **	-2.07 (3.56) *	-1.56 (6.52) *		

* Significant at a 1% level, two-tailed test

** Significant at a 5% level, " " "

*** Significant at a 10% level, " " "

TABLE 3. REGRESSION RESULTS (MEAN-TEST)

		R^2	RD	PAT	INV	WAGE	POP	MIL
8	Paper	0.09						
9	Textiles	0.12				-0.93 (1.89) ***		
11	Steel	0.08						
12	Aluminium	0.19					-0.38 (1.90) ***	1.22 (2.09) ***
15	Organic Chemicals	0.32	1.18 (3.19) *			-0.99 (2.02) **		
16	Inorganic Chemicals	0.33		-0.43 (2.06) ***	3.63 (2.31) **		0.31 (1.94) ***	1.43 (2.86) **
17	Colouring Materials	0.44		0.91 (4.12) *		-1.21 (2.39) **	-0.27 (1.76) ***	
18	Pharmaceuticals	0.38		0.78 (3.34) *	-2.86 (2.39) **	-1.21 (2.38) **	-0.36 (2.13) ***	
19	Fertilizers	0.20		-0.76 (2.61) **				1.36 (1.97) **
20	Plastics	0.37	0.90 (2.82) **			-1.17 (2.61) **		
22	Power Generating Machinery	0.54		0.39 (2.68) **			0.31 (2.65) **	
23	Special Machinery	0.58		0.67 (5.13) *		-0.73 (2.29) **		
24	Heating and Cooling Equipment	0.23		0.51 (2.71) **				
25	Pumps	0.45		0.64 (4.08) *				
26	Office Machinery	0.59			-1.91 (1.90) ***	-0.87 (1.90) ***	0.27 (1.90) ***	

27	Computers	0.40					0.39 (2.60) **	
28	Semiconductors	0.50	1.03 (2.48) **			-1.17 (2.24) **	0.41 (2.51) **	
29	Telecommunication Equipment	0.33	0.73 (2.48) **					
30	Machinery for Production & Distribution of Electricity	0.69		0.69 (6.34) *		-1.17 (4.36) *		
31	Consumer Electronics	0.52	1.04 (2.83) **				0.33 (2.15) **	-1.55 (4.32) *
32	Domestic Electrical Equipment	0.10				-0.81 (1.75) ***		
33	Instruments	0.57	1.12 (2.36) **	0.44 (1.92) ***				
34	Cars	0.46					0.69 (4.06) *	
35	Aircrafts	0.76					0.43 (4.07) *	0.73 (2.37) **
36	Ships	0.22	-1.43 (1.89) ***		8.43 (2.74) **			1.99 (1.97) ***
38	Metal Products	0.54		0.32 (3.69) *		-0.99 (4.58) *		
39	Furniture	0.05						
40	Clothing	0.42				-1.94 (3.82) *		

*Significant at a 1% level, two-tailed test

**Significant at a 5% level, " " "

***Significant at a 10% level, " " "

TABLE 4. REGRESSION RESULTS (TIME DIFFERENCE TEST)[1)]

		R^2	△RD	△ PAT	△INV	△WAGE	△ POP	△MIL
8	Paper	0.12		-0.49 (1.95) ***		0.83 (2.13) ***		-1.18 (1.77) ***
9	Textiles	0.21	0.39 (1.95) ***					
11	Steel	0.04						
12	Aluminium	0.16				1.05 (2.29) **		-1.49 (1.91) ***
15	Organic Chemicals	0.57			4.22 (5.17) *			
16	Inorganic Chemicals	0.18			1.48 (2.23) **			
17	Colouring Materials	0.14						0.70 (1.95) ***
18	Pharmaceuticals	0.53	0.89 (4.14) *		-1.02 (2.03) **	-0.40 (1.90) ***		
19	Fertilizers	0.29	1.65 (2.84) *					
20	Plastics	0.28			1.19 (1.83) ***			
22	Power Generating Machinery	0.48	0.78 (2.81) **		2.35 (3.37) *	0.79 (2.36) **		
23	Special Machinery	0.35		0.34 (2.67) **				0.68 (2.08) ***
24	Heating and Cooling Equipment	0.71			2.56 (3.55) *			
25	Pumps	0.62			2.06 (4.58) *	0.35 (1.78) ***		

26	Office Machinery	0.23	-1.03 (2.06) ***	0.70 (2.00) ***				
27	Computers	0.72			3.53 (3.10) *			3.32 (3.38) *
28	Semiconductors	0.33	0.94 (2.21) **		1.86 (1.94) ***			
29	Telecommunication Equipment	0.68		0.63 (4.40) *		-0.66 (2.80) **	0.37 (2.60) **	1.77 (4.67) *
30	Machinery for Production & Distribution of Electricity	0.66		0.20 (2.15) **	0.94 (2.71) **			0.65 (2.23) **
31	Consumer Electronics	0.52	0.82 (2.17) **		1.86 (2.08) ***			-1.36 (1.98) ***
32	Domestic Electrical Equipment	0.12						
33	Instruments	0.53		0.31 (3.25) *		-0.47 (2.97) *		0.92 (3.67) *
34	Cars	0.50	0.75 (2.77) **			0.80 (2.95) *		
35	Aircrafts	0.07						
36	Ships	0.06						
38	Metal Products	0.02						
39	Furniture	0.03						
40	Clothing	0.42	0.72 (2.37) **	-0.45 (2.21) **				-1.02 (2.15) **

*Significant at a 1% level, two-tailed test

**Significant at a 5% level, " " "

***Significant at a 10% level, " " "

1) Final period observation
less first period observation

TABLE 5. RANKING ACCORDING TO TECHNOLOGY-ELASTICITY

PATENTS MATTER:	OUR (mean-test)	SOETE (1987)[1]
1. Colouring Materials (17)	0.91	0.33/NS
2. Pharmaceuticals (18)	0.78	0.34
3. Machinery for Production and Distribution of Electricity (30)	0.69	0.67/0.62
4. Special machinery (23)	0.67	0.68/0.66/0.57
5. Pumps (25)	0.64	(0.49)
6. Heating and Cooling Equipment (24)	0.51	0.51
7. Power Generating Machinery (22)	0.39	0.47
8. Metal Products (38)	0.32	0.35
R&D MATTERS:		
1. Organic Chemicals (15)	1.18	NS
2. Consumer Electronics (31)	1.04	NS
3. Semiconductors (28)	1.03	(0.46)
4. Plastics (20)	0.90	0.31
5. Telecommunications (29)	0.73	(0.46)
BOTH PATENTS AND R&D MATTER:		
Instruments (33) (Patents)	0.44	0.74
(R&D)	1.12	

NOTE

1.This column contains estimates as reported by Soete for comparable (not identical) product groups. All estimates refer to patents.
Brackets: His classification is more aggregated than ours.
Several numbers: His classification is more dis-aggregated than ours.
NS = Not significant

GRAPH 1. FACTORS AFFECTING EXPORT SPECIALIZATION.